



Enclosure 2.0

Technical specifications and performance requirements InSAR products

The technical specifications and performance requirements listed below are defined as mandatory requirements. These requirements must be met. Providers who do not fulfil and comply with these technical specifications will be excluded from the procurement process.

Requirements Procurement	Yes	No
The bidder confirms with a legally valid signature that the listed Technical Specifications and Performance Requirements are met and complied with. Each page (7 pages in total) must be initialled.	<input type="checkbox"/>	<input type="checkbox"/>

Place, Date:

Company name:

First name(s), Last name(s):

Legal signature(s)

1. Specifications InSAR Data

1.1 Spaceborne InSAR Basic Data

As a data basis for the Switzerland-wide monitoring of surface motion, the data provided by the Sentinel-1 SAR constellation as part of the European Union's Copernicus Earth observation programme shall primarily be used (C-band, 5.405 GHz, IW TOPS SLC). These data are available from the 4th quarter of 2014 for Sentinel-1A and the 3rd quarter of 2016 for Sentinel-1B, and will have a 12 day repeat cycle per satellite and a 6 day repeat cycle in the constellation. Data from future satellites of the Sentinel-1 constellation must also be integrated into the products after their commissioning.

The Contractor is free to offer the integration of data from other satellite-based SAR systems at no additional costs.

1.2 Deliverables

The following data must be delivered as products in a standardised GIS format (CSV, ESRI Shapefile or GeoJSON for point data, GeoTIFF for raster data):

- Level 2a: Line-of-Sight (LOS) surface motion time series in radar geometry including the following metadata for each measurement point of the time series:
 - Date including respective surface motion value,
 - Unique ID,
 - Incidence angle,
 - Track angle,
 - Illumination/range direction,
 - Coherence,
 - ID of reference SAR scene [Master],
 - ID of co-registered SAR scene [Slave],
 - SAR acquisition parameters needed for geocoding,
 - Coordinates of the reference point.
 - Level 2b: LOS surface motion time series in map geometry including the following metadata for each measurement point of the time series:
 - Coordinates and official heights (height above geoid),
 - Date including respective surface motion value,
 - Mean annual surface motion value in LOS (*),
 - Annual standard deviation of the surface motion value in LOS (*),
 - Mean annual coherence (*),
 - Unique ID,
 - Incidence angle,
 - Track angle,
 - Illumination/range direction,
 - Coherence,
 - ID of reference SAR scene [Master],
 - ID of co-registered SAR scene [Slave],
 - Coordinates of the reference point.
- (*) Applies to annual deliveries only.
- Level 3: Surface Motion with components in east-west and vertical directions, based on the combination of overlapping ascending and descending scenes.

The Level 2a and 2b products are to be delivered as point data, the level 3 products as raster data.

1.2.1 Geometric properties of the InSAR products

At least the following geometric properties of the measured InSAR points are expected:

- **Point spacing and raster resolution:**

The point density should be as high as possible, without losing measurement points. The expected resolution is:

- Level 2a/2b (point spacing):
 - Approximately 5 x 20 m (equivalent to full resolution of Sentinel-1 IW SLC) when using the Permanent Scatterers (PS) approach.
 - <50 m when using the Distributed Scatterers (DS) approach with <150 fully resolved pixels per DS.
- Level 3 (raster resolution):
 - 50 x 50 m in a grid in integer LV95 coordinate values (cf. Section 1.3.1).
- **Precision of measurement:**
 - Level 2a: ± 0.005 m (1σ)
Standard deviation for any constant velocity point with reference to a local reference point (up to 10 km apart) and to a temporal frame.
 - Level 2b: ± 0.01 m (1σ)
Standard deviation between any two constant velocity points up to 50 km apart.
 - Level 3: ± 0.01 m (1σ)
Standard deviation for any points up to 50 km apart and with space-homogeneous and time-constant velocities.
- **3D geolocation accuracy:**
 - Level 2a: N/A
 - Level 2b: <10 m
 - Level 3: The required 3D geolocation accuracy of Level 2b limits errors during rasterization.

1.2.2 Schedule of deliveries

	Acquisition period	Delivery due date
1	Q4 2014 – 30.11.2020	3 months after signing the contract
2	01.12.2020 – 30.11.2021	31.12.2021
3	01.12.2021 – 30.11.2022	31.12.2022
4	01.12.2022 – 30.11.2023	31.12.2023
5	<i>01.12.2023 – 30.11.2024</i>	<i>31.12.2024</i>
6	<i>01.12.2024 – 30.11.2025</i>	<i>31.12.2025</i>

Deliveries 5 and 6 must be offered as separate annual options.

1.2.3 Concept for more frequent deliveries

More frequent data processing and deliveries, temporally close to the most recent data acquisition at different intervals (e.g. every 6 or 18 days) may be offered as separate options in the concept, at least one option is mandatory (in accordance with Enclosure 3.1). The time delay between data acquisition and product delivery shall also be mentioned in the option(s).

1.3 InSAR data characteristics

1.3.1 Reference frame and position/height coordinate systems

All level 2b and level 3 products (position and displacement measurements) are to be processed either in the Swiss reference system CH1903+ (reference frame LV95/LHN95, EPSG:2056/EPSSG:5729) or in the reference system ETRS89 (reference frame ETRF93, EPSG:7922 or EPSG:7923).

The quality control of the data will be carried out using the InSAR products of level 2b in LV95/LHN95.

Transformations must be performed using the REFRAME software (provided by swisstopo) and the current geoid (CHGEO2004).

1.3.2 Point density

The required minimum point density must be met. Point densities are expected according to the table below; the higher value corresponds to the target value (which can be exceeded), the lower value corresponds to the minimum point density to be achieved. Cases of point densities falling below the stated minimum values have to be determined and analysed by the contractor, and justified to the requesting unit. CORINE Land Cover (version 2018), which is provided as part of the Copernicus Land Monitoring Service, serves as a reference for the land cover classes. The point density determination is based on the CORINE Land Cover classes listed below.

Land Cover Class (cf. CORINE Land Cover, Version 2018)	Point density per km ²
1.1.1 Continuous urban fabric	5,000 – 10,000
1.1.2 Discontinuous urban fabric	1,000 – 5,000
1.2 Industrial, commercial and transport units	1,000 – 5,000
3.3 Open spaces with little or no vegetation	400 – 1,000

1.3.3 Data gaps

Data gaps are allowed in areas with permanent or during seasonal occurrence of

- Agricultural areas
- Water bodies
- Snow/ice cover
- Construction sites
- Tall vegetation

and topographically induced effects such as layover and shadow.

Major data gaps that cannot be assigned to one of the above areas, are to be documented, reported by means of a shapefile and discussed with the requesting unit. The gaps identified by the contractor shall be reviewed by the requesting unit. Unsubstantiated gaps shall be corrected by the contractor. The contractor shall provide a layover/shadow map per relative orbit in a standardised GIS raster format (see Section 1.2).

2. Implementation of data evaluation and processing

2.1 Methodology

Surface displacements must be measured using the Persistent Scatterer Interferometry (PSI) approach. A combination of permanent scatterers (PS) and distributed scatterers (DS) must be used, including hybrid methodologies.

2.2. Requirements regarding preparation and execution of data production

2.2.1 Preparatory work

The contractor shall prove the availability and readiness for use of suitable algorithms as well as processing and storage capacities of the production system, enabling the generation of the products in the required quality and within the time limits. Obtaining the satellite data is the sole responsibility of the contractor. The ability to process and use the DEM and GNSS data provided by the requesting unit within the scope of product manufacturing must also be ensured and demonstrated.

2.2.2 Acquisition period and extent

The contractor must cover the period starting with the commissioning of Sentinel-1 A (Q4 2014, IW SLC mode only). Up to the commissioning of Sentinel-1 B (Q3 2016), this corresponds to a nominal 12 day repeat cycle per ascending and descending orbit, followed by a 6 day repeat cycle per ascending and descending orbit. The product to be delivered covers the entire area of Switzerland and the Principality of Liechtenstein, including a 5 km buffer surrounding the two countries.

2.2.3 Method of execution

The contractor shall propose proven methodologies and algorithms with documented quality and applicability. The methods and algorithms used are to be documented in the concept in a transparent and comprehensible manner.

The contractor is advised to specify the methodological approach chosen for the production of the surface motion products with reference to peer-reviewed scientific literature or reports.

2.2.4 Documentation of SAR data processing

All processing steps and external data used for processing the SAR scenes and producing the point data must be described and documented in English. This report must be made available to the requesting unit starting with the first data delivery for quality control and acceptance at the same time as the data delivery.

For the different products of levels 2a, 2b and 3, at least the following points shall be documented with regard to the chosen methodology:

- Level 2a
 - Image co-registration,
 - Interferogram formation (filters and corrections applied, multi-looking, temporal baseline),
 - Selection and size of the processing unit,
 - Selection of the measurement points candidates (PS, DS, or hybrid methods),
 - Filter criteria of the measuring points,
 - Mitigation strategy to manage areas with seasonal snow coverage,
 - Criteria for the selection of reference points,
 - Mitigation strategy regarding ionospheric path delays,
 - Phase unwrapping and deformation model used.
- Level 2b
 - Characteristics and accuracy of the horizontal reference frame, vertical and dynamic earth effects models,
 - Reference frame of ground points,
 - Reference frame of LOS deformation vectors,
 - Harmonization strategy of level 2a data.
- Level 3
 - Spacing of the reference grid,
 - Decomposition methodology applied to derive the vertical and east-west components and to calculate the raster values,
 - Dependence on the quality of level 2b product.

2.3 Quality control of the products

2.3.1 Quality control by the contractor

For each product level, specific quality control parameters and procedures are to be defined by the contractor and already documented in the concept for the tender to ensure that the results meet the requirements. Quality control should be automated as far as technically possible. The contractor shall provide standardised GIS data sets (e.g. as ESRI shapefiles) in which, as far as possible, the spatial variability of the quality control parameters is evident. The proposed quality control parameters and procedures include:

- Temporal coherence
- RMSE of a time series with respect to a fitted model,
- Point density for each CORINE Land Cover class listed in Section 1.3.2 (expressed in points per km²). Guiding values are given in Section **Fehler! Verweisquelle konnte nicht gefunden werden.**,
- Consistency of point density, surface motion estimation and time series for areas covered by orbits with different acquisition geometries,
- Study of tile/burst/swath overlaps between neighbouring tracks,

- Comparison with GNSS stations,
- Analysis of variograms of short temporal baseline interferograms before and after the atmospheric correction,
- Consistency of stable targets in the vicinity of the reference point,
- Comparison with artificial reflectors with known backscatter properties.

The contractor is free to propose additional solutions.

2.3.2 Quality control by the requesting unit and acceptance conditions

After delivery of the data, the requesting unit carries out a check of the products for approval, the decisive product being the level 2b product. This control is based on the quality control parameters listed in Section 2.3.1 Quality control .

2.3.3 Deliverables

The data shall be delivered by means of a NAS system (Network Attached Storage) provided by the contractor or an encrypted and secure (sFTP) server solution. If the data is delivered on a NAS, it shall be returned to the contractor after copying to the requesting unit's servers. Aside from retroactive and annual deliveries, the (sFTP) server solution must be used.

2.4 Data delivery process

The data delivery is carried out with an initial data delivery and, after a quality control by the requesting unit, with further deliveries at least once a year (see Section 1.2.2).

2.4.1 Initial data delivery

As part of the quality assurance, the contractor is required to make the earliest possible initial delivery of the products for the acquisition period between Q4 2014 and 30.11.2020.

The contractor shall deliver within this area:

- Products according to Sections **Fehler! Verweisquelle konnte nicht gefunden werden.** und 1.3,
- Point density maps (250 m x 250 m grid) in LV95
- Proof of elevation and position accuracy based on control surfaces and the station logs of the GNSS reference stations used,
- Statistical key figures regarding the accuracy and precision of the surface motion products compared with GNSS reference stations.

The requesting unit carries out an inspection immediately after the delivery of the products, in particular:

- that the required products have been fully delivered for the period,
- that the required products have been provided with the requested accuracy.

The contractor is informed of the result of the inspection and the further procedure is defined.

2.4.2 Continuous deliveries

Annual deliveries include acquisitions until 30 November and are made by 31 December of each year at the latest in accordance with Section 1.2.2. The deliveries always include the products listed under Section 1.2 and 1.3 as well as the documents and reports in accordance with Section 3.2 for each subarea delivered.

Prior to the acceptance of a partial delivery, an inspection is carried out by the requesting unit. The requesting unit shall draw up a report on the inspection and its results, which shall be sent to the contractor.

If the inspection reveals insignificant defects, the acceptance of the partial delivery shall nevertheless take place upon completion of the inspection. The contractor must remedy the defects found within the set period of time and informs the requesting unit of their remedy.

If the inspection reveals significant defects, acceptance shall be postponed. The contractor must immediately remedy the defects identified and submit the products to the requesting unit in due time for a new inspection. If acceptance is postponed and the contractual acceptance date is thereby exceeded, the contractor is in default.

3. Reporting

The contractor shall prepare interim and final reports for the requesting unit for the duration of the project in accordance with the criteria set out below. These reports are to be written in English and delivered digitally (PDF) to the Customer. In addition, the contractor shall inform the requesting unit of any deficiencies and risks as soon as they are known, e.g. gaps in the satellite data, problems regarding the product generation, needs for external data from the requesting unit, potential measures to reduce consequences if agreed deadlines cannot be met, etc.

3.1. Interim quality reports

Continuous quality control during the production process with interim quality reports for the requesting unit is expected. The contractor guarantees at least half-yearly reports on the status of production, including documentation and presentation regarding quality control. In case of deliveries with shorter intervals, changes in production parameters shall also be documented in a report.

3.2 Reporting upon deliveries and project completion

The contractor shall deliver the following documents to the requesting unit with the initial delivery and the interim deliveries, which shall be made at least annually, as well as upon completion of the project:

- A technical report on the entire project. This report contains the description of all processing steps and procedures as well as the naming of the algorithms and programmes that were used to process the SAR data and to derive the products. This report includes at least the elements listed in Section 2.2.4 Documentation of SAR data pro.
- All documents needed to prove the quality of the processed surface motion products, in particular those to prove the accuracy of elevation and position as well as the point density achieved (cf. Section 2.4.1).